FIXOR™ - A NEW APPROACH TO NEUTRALIZING LANDMINES AND UXO

C. J (John) Anderson, Manager Explosives Research and Development
A.W. (Bill) Bauer, Vice President
MREL Specialty Explosive Products Limited
1555 Sydenham Road
Kingston, Ontario, CANADA K7L 4V4
Phone: 613-545-0466
Fax: 613-542-8029
E-mail: FIXOR@mrel.com

Abstract

There are always security concerns when explosives are transported and stored, and these concerns are intensified in peacekeeping operations where explosives could fall into the wrong hands. MREL Specialty Explosive Products Limited has developed FIXOR™, a new approach to neutralizing landmines and unexploded ordnance (UXO). The product consists of two precursors: a flammable liquid in one plastic container and a totally inert powder in another; neither of these precursors is classified as explosives. Both precursors are approved for transport by land, sea, cargo and passenger airfreight. The precursors are mixed to form an explosive immediately prior to placement next to the UXO or landmine. Initiation is by blasting cap or detonating cord.

The detonation velocity and detonation pressure for the explosive mixture have been determined using both experimental techniques and/or theoretical calculations. The use of FIXOR™ as an explosive neutralization device for landmines and UXO in humanitarian demining scenarios involved the evaluation of more than 75 field trials; these trials were conducted by MREL Specialty Explosive Products Limited at Canadian and American Defence Facilities and in an international venue (Kosovo). The trials demonstrate that FIXOR™ is effective against a wide variety of landmines and other munitions. The trials also confirm that the product is much safer to handle and transport than conventional explosives. The option of storing the precursors in separate locations is making a contribution to security in demining operations in mine affected countries.

This paper describes the FIXOR™, its chemical and detonation characteristics and presents the results of the various field trials.

INTRODUCTION

Since 1984, the MREL Group of Companies has been conducting research into the effectiveness of explosive dusts, explosive foams, explosive liquids, and shaped charges against landmines for eventual integration into minefield breaching and minefield clearance systems. However, there are security and cost concerns when explosives are transported and stored. These concerns are intensified during Peacekeeping and Humanitarian Demining operations in geographical areas of conflict.

In 1998, the explosives research efforts turned to development of a two component (binary) explosive system. The goal was to use relatively inexpensive components that were not explosive, and could be easily transported around the world by commercial airfreight with minimal logistics and at a low cost. In addition, the components would be easily mixed at the minefield to produce an explosive which could substitute for the more expensive plastic and block TNT explosives commonly used to destroy landmines and unexploded ordnance (UXO). This technique is known as "blow in place" or BIP.

In November 1998 the research efforts resulted in the successful detonation of a binary explosive system. Further investigations have characterised and customised the system with the eventual goal of independent verification of its performance against landmines and UXO. Patents are pending.

This newly developed binary explosive system has been termed FIXOR™, an acronym for Field-friendly, Inexpensive, uneXploded Ordnance Remover. Several test programs involving the use of FIXOR™ against a variety of landmines and UXO have been conducted. This paper provides a description of the FIXOR™ and summarises the results of the various field trials.

About FIXOR™

The FIXOR™ is a binary flammable liquid-based explosive kit. It has been designed to complement and/or replace the use of purchased plastic explosives and block TNT as traditional demining and UXO explosive charges.

As shown in Figure 1, the FIXOR™ consists of two precursors, a flammable liquid (FIXOR™ Liquid, UN 2842, NSN 1375-21-920-4587) in one 500 ml plastic container; and a totally inert powder (FIXOR™ Powder, NSN 1375-21-920-4638) in another 500 ml plastic container. Neither of these precursors is classified as explosives. Unlike binary nitromethane-based explosives, both FIXOR™ precursors are formally approved for transport by land, sea and commercial passenger airfreight.

In the country of use, FIXOR™s can be stored and transported as a flammable liquid and changed into an explosive by the deminer at the minefield when required. The precursors are mixed to form a Class 1.1D explosive (FIXOR™ Explosive, UN 0048) immediately prior to placement next to the UXO or landmine. Initiation and detonation of the FIXOR™ Explosive is by blasting cap or detonating cord. The goal of the FIXOR™ is to cause sympathetic detonation of the landmine or UXO immediately upon detonation of the FIXOR™ Explosive.

The FIXOR™ precursors are not an explosive until the contents of the two bottles are thoroughly mixed together. If the contents of the FIXOR™ precursors or FIXOR™ Explosive are spilled, they are not harmful to the deminer or to the environment. The FIXOR™ Explosive is very safe to handle and deploy however it must be treated with respect; after all it is a detonator-sensitive explosive.

After several hours of remaining unshaken, the FIXOR™ will not detonate when fired by a detonator or by detonating cord. This is by design as it makes the FIXOR™ an unlikely candidate for misuse by hostile groups as a "booby-trap" or terrorist device. Unless the FIXOR™ is re-shaken, it will act as a flammable liquid.

The FIXOR™ has been designed to integrate seamlessly with demining training methods and operating procedures in use throughout the world. FIXOR™s are easily and safely deployable by indigenous deminers and require no ongoing field technical support. FIXOR™s are fully functional under all demining weather conditions. Figure 2 is a schematic illustration of the procedure for making FIXOR™ Explosive at the minefield.

TECHNICAL CHARACTERISTICS OF THE FIXOR™

The following technical details have been established for the FIXOR™ Liquid and FIXOR™ Powder:

FIXOR™ Liquid

a) Color: red;
b) NATO Stock Number: 1375-21-920-4587;
c) Classification: Class 3 Flammable Liquid, UN 2842. Packing Group III;
d) Health/Environmental Concerns: use in ventilated areas or outdoors, MSDS is available;
e) Inner Packaging: 500ml plastic bottle with removable plastic lid. L x W x H: 3 x 2 ¼ x 6";
f) Shelf life: indefinite;
g) Settling: shake to remix before adding to FIXOR™ Powder;
h) Outer Packaging: Complies with UN requirements for commercial air transport of flammable liquids. UN Approved 4GV/X22.7/S/99. 24 ea. bottles per box;
i) Box dimensions: 23¾ x 15 x 10¼ ";
j) Gross weight per box: 30.9 lbs;
k) Net weight of flammable liquid per box: 18.7 lbs.

FIXOR™ Powder

a) Color: orange/white;
b) NATO Stock Number: 1375-21-920-4638;
c) Classification: inert powder;
d) Health/Environmental Concerns: none.
e) Inner Packaging: 500ml plastic bottle with removable plastic lid. Lid is prepared for detonator/detonating cord insertion. L x W x H: 3 x 2 ¼ x 6".
f) Shelf life: indefinite;
g) Settling: shake to loosen powder before adding FIXOR™ Liquid;
h) Outer Packaging: 24 ea. bottles per box;
i) Box dimensions: 20 x 9¾ x 6½";
j) Gross weight per box: 5.6 lbs.

When these two components are combined as shown in Figure 2, the resulting mixture is a "cap-sensitive" explosive. The velocity of detonation (VOD) for this mixture, when placed in a 5 cm inner diameter plastic (PVC) tube, was determined to be approximately 4300 m/s. Figure 3 illustrates the VOD trace acquired using the continuous resistance wire technique. This value compares well with a calculated value of 4333 m/s, obtained using CHEETAH 2.0 with the BKWC library.[1] The estimated detonation pressure for this mixture is of the order of 40 – 44 kbar, using either CHEETAH 2.O or a typical formula to estimate the pressure ($P = \bullet D^2/4$), where • is formulation density and D is the velocity of detonation).[2] In addition, air-blast measurements have been conducted; the results indicate that by this method the TNT equivalency of the FIXOR™ is of the order of 80-85% TNT. It should be noted that the use of other methods for this measurement would undoubtedly provide somewhat different results, based on the differences in brisance which exist between TNT and FIXOR™.

The following technical details have been established for the FIXOR™ explosive blend:

FIXOR™ Explosive

a) Color: orange;
b) Classification: Class 1.1D explosive, Charges, demolition UN 0048;
c) Net Explosive Weight: 0.9 lbs;
d) Density: 0.9 g/cc;
e) Velocity: 4,300 m/s (14,100 ft./sec.) based on testing to date;
f) TNT Equivalency: approximately 80-85% by weight based on air-blast;
g) Operational Temperature Range (tested): -20° to +110° F (-30° to +40° C);
h) Operational time: within 2 hours of mixing, or remix by shaking before detonating;
i) Shelf life: indefinite;
j) Initiation: ULI ("hangman") knotted 50 grain/ft. detonating cord or detonator (∃0.8 g PETN).

EFFECTIVENESS OF FIXOR™ AGAINST LANDMINES AND UXO

Three basic configurations for neutralization of landmines/ordnance can be utilized. These configurations allow increasing amounts of explosive power (shock) to be imparted to the target, depending on the hardness/toughness of the target casing.

Standard Attack Configuration:
Involves placement of one FIXOR™ adjacent to a target. Typically used for small, plastic cased antipersonnel landmines: Figure 4(a) is a photograph of this attack configuration against a VS 50 AP landmine. A #12 equivalent detonator (≥ 0.8 g PETN) or knotted detonating cord is used to initiate the FIXOR™.

Counterforce or "Earmuff" Attack Configuration:
Involves placement of two FIXOR™s on opposite sides of a target. Typically used for larger AP mines and various plastic or thin steel – cased (but not hardened) Antitank landmines: Figure 4(b) is a photograph of this attack configuration against a TMA-5 landmine. Knotted detonating cord lines (or "sensitized detonating cord" – detonator double crimped on the cord end) are used for simultaneous initiation of the FIXOR™s. This method of initiation is strongly recommended to ensure simultaneous detonation of more than one FIXOR™. This is because some commercial "instantaneous" detonators have demonstrated initiation time scatter.[3]

Focussed Energy Attack Configuration:
Filling the FIXOR™ completely with FIXOR™ Explosive can enhance the performance of an individual FIXOR™ by "topping-up" the container with the explosive from another FIXOR™. This increases the net explosive weight from 400 grams (0.9 lbs.) to approximately 500 grams (1.1 lbs.) per FIXOR™. One (1) FIXOR™ can be used to top-up four (4) other FIXOR™s as follows: mix five (5) FIXOR™s and use one to fill up the other four. Pointing the bottom of the FIXOR™ towards the target, and using the shaped charge or Monroe effect, from the bottom end of the FIXOR™ enhances the performance of the "topped-up" FIXOR™. Two or more FIXOR™s can be used to focus the energy on hardened targets. Figure 4(c) is a photograph of a four FIXOR™ attack configuration for sympathetic detonation of a 155 mm artillery round.

TARGETS NEUTRALIZED
The following targets have been neutralized using selected variations of the above attack configurations:

AP Mines: VS50, M16, M18, PMA-1, PMA-2, PMA-3, BLU-92/B

AT Mines: M19, M21, Mk 7, TMA-5, TMA-3, PT-Mi-Ba III

UXO: M67 grenade, 81 mm HE mortar, 81 mm WP mortar, 40 mm HE round, BLU 97 submunition, LUU-II flare, MJU-7 flare, 76 mm recoilless rifle round, AIM 9 Gulf Sidewinder Seeker Head (copy), 105 mm Artillery Round, 155 mm Artillery Round, M1A2 Bangalore, 40 lb. Cratering Charge, Mk 82 500 lb. bomb.

The flares are shattered and the pyrotechnic contents burn. The WP mortar is shattered and the WP reacts with the air. The Mk 82 bomb may be low-ordered (split into large shell casings and some broken explosive) or high-ordered (full detonation) depending on the FIXOR™ attack configuration. All other targets are neutralized through high-order sympathetic detonation. Suggested Standard Operating Procedures (SOPs) for the neutralization of the above mines and UXO can be found at the website: www.FIXOR.com. Users may submit their own successful SOP's/UXO neutralization techniques and photographs for inclusion in this site. FIXOR™ is currently being utilized in central and northeast Africa, and in Southeast Asia.

CONCLUSIONS AND COMMENTS

1. The FIXOR™ is an effective method for neutralizing landmines and UXO in place.

2. The FIXOR™ integrates seamlessly with current blow-in-place procedures.

3. When compared to conventional explosives, the FIXOR™ has significantly less hazards and less logistical requirements during transport and storage.

4. When utilizing detonating cord to initiate detonation of the FIXOR™, the end of the detonating cord should be tied into a "Uli" knot (similar to a hangman's knot) with at least six (6) turns in it to ensure detonation of the FIXOR™. Details on the Uli knot are contained on the FIXOR™ web site at www.FIXOR.com.

5. The distance from the end of the detonator, or from the end of the Uli knot in the detonating cord, to the top of the FIXOR™ cap should be marked by the deminer at a length of 9 cm (3.0 inches) to ensure proper placement inside the FIXOR™.

6. When the simultaneous detonation of multiple FIXOR™s is required for a particular demining task, the deminer should not rely upon the timing accuracy of multiple electric or non-electric detonators – even if the detonators are "zero" delay detonators. It is preferable to use a piece of Uli knotted detonating cord in each of the FIXOR™s and initiate the lengths of detonating cord simultaneously with one detonator. Alternatively, "sensitized" detonating cord, which comprises an appropriate strength detonator crimped to the end of the cord, can be used in place of knotted detonating cord. Details on simultaneous detonation of multiple FIXOR™s are found on the FIXOR™ web site.

7. When attacking larger, thick walled UXO such as the 105 and 155 mm HE Artillery Rounds or a Mk 82 500 lb. bomb, additional FIXOR™s should be mixed and their explosive contents used to completely fill the FIXOR™s deployed against the UXO. This "topping up" process provides up to 500 g of FIXOR™ explosive in a FIXOR™ as opposed to the standard 400 g and allows the FIXOR™s to be placed on their sides and detonated reliably. Details on this procedure are contained on the FIXOR™ web site.

ACKNOWLEDGEMENTS

The Authors wish to express their sincere gratitude to the Management and Staff of the Canadian Centre for Mine Action Technologies (CCMAT) and the Defence Research Establishment Suffield for their field trials of the effectiveness of the FIXOR™ for demining and UXO neutralisation. The Authors also express their gratitude to UNMIK/MACC, CCKFOR/NCE and CCKFOR/OC for their efforts in co-ordinating the field trials of FIXOR™ in Kosovo. The authors express their gratitude to the EOD community of the USAF, USMC, USA and USN for trials conducted at Nellis AFB, Fort Campbell and Blossom Point.

REFERENCES

1. Fried, Lawrence J., CHEETAH 2.0, Lawrence Livermore National Laboratory (1999).

2. Cooper, Paul W., Explosives Engineering, VCH Publishers, NY (1996).

3. MREL, internal research.

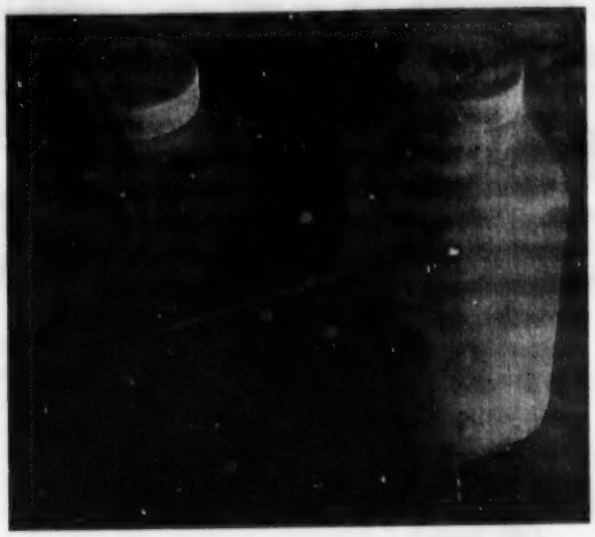

FIGURE 1: PHOTOGRAPH OF FIXOR™ LIQUID AND FIXOR™ POWDER.

FIGURE 2: SCHEMATIC DIRECTIONS FOR THE USE OF FIXOR™.

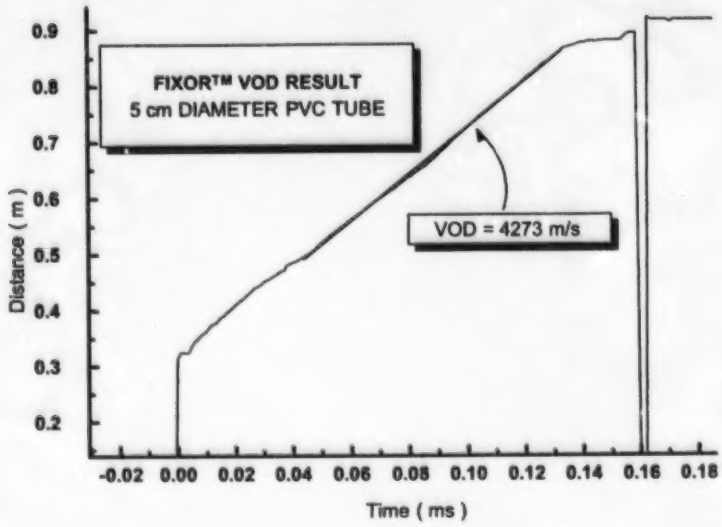

FIGURE 3: VELOCITY OF DETONATION FOR FIXOR™ EXPLOSIVE.

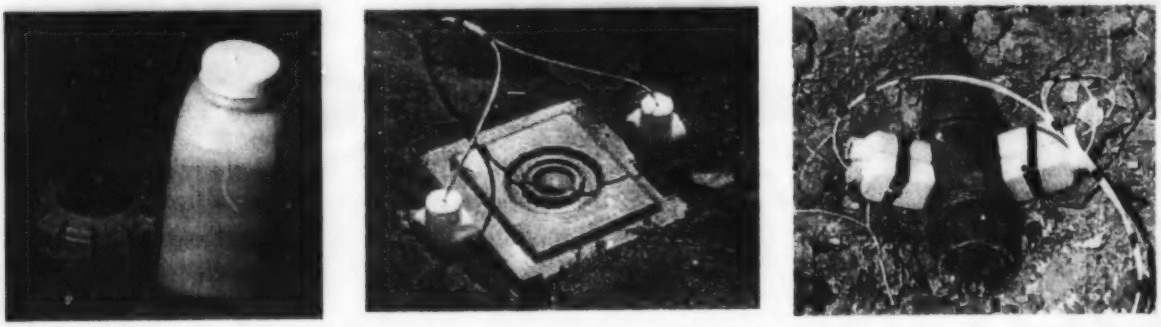

FIGURE 4: PHOTOGRAPHS OF THE THREE ATTACK CONFIGURATIONS USED FOR NEUTRALIZATION OF LAND MINES AND UNEXPLODED ORDNANCE:

A) STANDARD ATTACK CONFIGURATION;
B) COUNTERFORCE OR "EAR-MUFF" ATTACK CONFIGURATION;
C) FOCUSSED ENERGY ATTACK CONFIGURATION.